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OPERATIONAL RESEARCH DIVISION

RESEARCH NOTE 9601

AN ANALYSIS OF THE PURCHASE AND DELIVERY COSTS OF JP-8 AVIATION FUEL

BY

P.E. Desmier

106-03433/

AIR COMMAND

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Approved by:

P.E. Desmier
Deputy Chief of Staff
Operational Research

WINNIPEG, CANADA JULY 1996

ABSTRACT

Operational Research Division Project Report 95/1 [1] compared the quantitative and qualitative factors associated with the conversion to JP-8 aviation turbine fuel for Canadian Forces (CF) land-based aircraft. Financially, the study concluded that a conversion from JP-4 to JP-8 would result in an annual net loss to the CF of approximately $2.6M.

This Research Note, a follow-up study to [1], provides a more accurate purchase and delivery comparison between JP-8 and JP-4 for all Air Command wings and bases that maintain significant flying operations. Based on a statistical cost analysis for 12 wings and bases (vice four in reference [1]), it is now concluded that the total annual mean gain in converting to JP-8 fuel would be approximately $2.07M.

Regardless of any cost benefit associated with the purchase and delivery of JP-8 fuel relative to JP-4, DND has no intention of switching from JP-4 to JP-8 for at least the next five years largely due to the increased maintenance costs as a result of using JP-8 in older CF aircraft. If and when DND decides to pursue the use of JP-8 in all airframes, this study will serve as the foundation for a future cost benefit analysis.

RESUME

Dans le rapport de projet 95/1 [1] de la Division - Recherche opérationnelle, on compare les facteurs quantitatifs et qualitatifs liés à la conversion au carburéacteur JP-8 pour les aéronefs à base terrestre des Forces canadiennes (FC). Sur le plan financier, l'étude a permis de conclure que le passage du JP-4 au JP-8 se traduirait par une perte annuelle nette d'environ 2,6 millions de dollars pour les Forces canadiennes.

Le présent compte rendu de recherche, qui constitue une étude de suivi à [1], offre une comparaison plus précise des coûts d'achat et de livraison des carburéacteurs JP-8 et JP-4 pour toutes les escadres et les bases du Commandement aérien qui administrent d'importantes opérations aériennes. À partir d'une analyse statistique des coûts portant sur 12 bases et escadres (leur nombre n'était que de quatre dans le document de référence [1]), on peut maintenant conclure que le gain annuel moyen de la conversion au carburant JP-8 serait d'environ 2,07 millions de dollars.

Quels que soient les avantages économiques découlant de l'achat et de la livraison de JP-8, le MDN n'a pas l'intention de faire la transition du JP-4 au JP-8 au cours des cinq prochaines années, principalement en raison des coûts d'entretien accrus liés à l'usage de JP-8 dans les aéronefs plus anciens des FC. Dans le cas où le MDN décide de recourir au JP-8 pour tous les types d'aéronefs, cette étude servira de point de départ pour une future analyse de rentabilité.

ACKNOWLEDGEMENT

The author wishes to extend his sincere appreciation to Mr. Richard Menard of Public Works and Government Services Canada for providing the fuel costs for each wing and base and for many useful comments regarding the manuscript.

TABLE OF CONTENTS

ABSTRACT/RESUME i

ACKNOWLEDGEMENT ii

1 - INTRODUCTION 1

Background 1

Assumptions 1

2 - DISCUSSION ON THE AVAILABILITY AND USE OF JP-8 FUEL 2

Availability of Product 2

Refiners Capability 2

Quantity and Delivery Method 3

Commercial Competition 3

DND Viewed as Second Preferred Customer 3

Maintenance Costs 3

3 - THE ANALYSIS 4

Fuel Volume 4

Fuel Costs 5

Fuel Analysis 6

4 - DISCUSSION 8

5 - CONCLUSIONS 9

REFERENCES 10

AN ANALYSIS OF THE PURCHASE AND DELIVERY COSTS OF JP-8 AVIATION FUEL

1 - INTRODUCTION

Background

1. Operational Research Division Project Report 95/1 [1] compared the quantitative and qualitative factors associated with the conversion to JP-8 aviation turbine fuel for Canadian Forces (CF) land-based aircraft. The potential economic impact of conversion was studied for 4 Wing Cold Lake, 8 Wing Trenton, 14 Wing Greenwood and 19 Wing Comox. The operational impact of conversion was studied for the CF-18A (Hornet), the CP-140 (Aurora) and the KC-130 (Hercules) aircraft.

2. Financially, the study concluded that a conversion from JP-4 to JP-8 would result in an annual net loss to the CF of approximately $2.6M. It was further specified that this net loss was highly sensitive to the JP-8 purchase price due to the large volumes of fuel that must be purchased. As a result, it was recommended that further analysis be conducted on the financial implications of conversion with more accurate costs for production and implementation into service of JP-8 fuel.

3. Based on the above, the Deputy Chief of Staff Operational Research was asked by the Deputy Chief of Staff Logistics (DCOS Log) to conduct a follow-up analysis to assess the economic impact of converting to JP-8 at all bases and wings that support flying operations [2]. This Research Note provides a more accurate purchase and delivery comparison between JP-8 and JP-4 for 3 Wing Bagotville, 4 Wing Cold Lake, 8 Wing Trenton, 12 Wing Shearwater, 14 Wing Greenwood, 15 Wing Moose Jaw, 17 Wing Winnipeg, 18 Wing Edmonton, 19 Wing Comox, CFB Gagetown, CFB Petawawa and CFB Valcartier.

Assumptions

4. The methodology used to calculate the projected purchase and delivery cost savings that would be achieved from the use of JP-8 is based on the following assumptions [3]:

   a. It is assumed that a denser fuel such as JP-8 combusts with the same efficiency as JP-4 and that an approximate 6% increase in density would translate into an approximate 6% decrease in required fuel volume.

b. The unit price differential between JP-4 and JP-8 can vary from one delivery location to another. This study is based on a statistical analysis which attempts to account for the cost differential through statistical distributions in historical fuel costs. However, since JP-8 costs could only be obtained for 19 Wing, it is assumed that the ratio of JP-8 to JP-4 costs for 19 Wing is applicable in calculating the JP-8 costs for all other wings and bases.

c. Local supply and demand, market conditions and company strategies play a very important role in the formulation of a unit price for petroleum products. These factors are next to impossible to project with any form of accuracy.

d. Increased maintenance costs as a result of using JP-8 have not been factored into this study. This analysis simply investigates the cost differential involving the purchase and delivery costs of JP-8 relative to JP-4.

2 - DISCUSSION ON THE AVAILABILITY AND USE OF JP-8 FUEL

Availability of Product

5. JP-8 fuel (NATO Code 'F-34') is basically Jet A-1 fuel (a kerosene based aviation turbine fuel) plus three military additives. These additives are: fuel system icing inhibitor (FSII), corrosion inhibitor/lubricity improver additive, and static dissipater additive [1]. Presently, the only pure JP-8 fuel being produced in Canada is available in Goose Bay, Labrador.

6. As discussed in [4], the cost advantage associated with JP-4 has been disappearing gradually due to reducing JP-4 refinery production in Canada. It is expected that this cost advantage will soon belong to JP-8 because there will be less competition for supplying JP-4. If the Department of National Defence (DND) was to convert to JP-8 throughout Canada, JP-4 production would quickly be eliminated. Refiners would stop producing JP-4 in order to satisfy DND's requirements for JP-8 [5].

Refiners Capability

7. There is no doubt that all major refiners have the technology to produce JP-8 fuel. Consultation with the petroleum industry and Public Works and Government Services Canada (PWGSC) would be required to determine the period of time needed to convert from JP-4 to JP-8 [3].

Quantity and Delivery Method

8. Refiners would be very reluctant, if not adamant, at supplying JP-8 fuel to locations where quantities would be considered minimal. In particular, supply might not be available to locations that would require extensive changes or additions to their delivery network [4].

Commercial Competition

9. Commercial airlines use Grade Jet A-1 fuel. DND's potential demand for JP-8 would put a strain on the availability of the Jet A-1 product, possibly causing shortages, resulting in further price increases [4].

10. DND represents a very small portion of the total oil company aviation fuel business. The unpredictable nature of DND's call-ups to standing offers, with respect to quantities and annual usage patterns, compared to airline business may result in oil companies being unwilling or unable to satisfy DND's needs. Furthermore, the requirement to have fuel delivered with the necessary additives may also affect product availability and cost [4].

DND Viewed as Second Preferred Customer

11. Refineries dealing directly with commercial aviation companies are provided with firm quantities to quote on as opposed to government requirements where there are no firm commitments. In addition, DND's estimates have not always materialized in the past. To make matters worse, DND's actual consumption rate is unpredictable.

12. In addition, government payment policy is to reimburse the suppliers within 30 days from receipt of an invoice. Private industry pays invoices, in some cases, within two days [4].

Maintenance Costs

13. The greatest issue from DND's, and in particular Air Command's perspective, is the use of JP-8 in older aircraft. JP-8, in essence, does not operate properly in older combustion chambers. Fuel leaks through seals could occur; also JP-8 is known to increase coking or carboning of the fuel nozzles and combustion chambers thereby increasing the requirement for more aircraft maintenance. Based on this issue alone, and as stated in [5], "Air Command has determined that the switch to JP-8 fuel would not be appropriate at this time".

3 - THE ANALYSIS

14. In response to the tasking by DCOS Log, a cost and delivery comparative analysis was conducted for those Air Command wings and bases that support flying operations and that require between 750,000 L and 145×10^6 L of JP-4 aviation fuel as the maximum amount listed on DND's requisition (see Table 2).

15. As shown in Table 1, the primary differences between JP-4 and JP-8 include volatility, density and the volumetric heat of combustion. Since JP-8 is approximately 6% denser with more BTU's per litre, it stands to reason that the volume required of JP-8 would also be approximately 6% less than that required of JP-4.

Property	*JP-4*	*JP-8*
Density, kg/m^3	750 - 801	774 - 839
Density (Normal Average) (lb/gal)	6.34	6.71
Freezing Point, °C	-58	-47
Flash Point, min, °C	-29	+38
BTU's Per gal, min	115,000	119,000
Vapour Pressure, KPA (range)	14 - 21	0
Initial Boiling Point, °C (range)	142	329

Table 1. Comparison of JP-4 and JP-8 Fuel Properties

Fuel Volume

16. Table 2 lists the wing or base used in the analysis, the maximum quantity of JP-4 fuel, the mean cost of the fuel and the equivalent volume of JP-8 fuel. However, the maximum quantity is not always ordered over the period of one year. For example, in the period August 1994 – July 1995, 4 Wing ordered only 100 x 10^6 L of JP-4 and not the maximum as reported in Table 2. Therefore, for statistical purposes, fuel volume is deemed to follow a triangular distribution $F(x)$ with domain

$$a \le x \le c \ , \tag{1}$$

where

a = minimum quantity = $60\% \times c$
b = most likely quantity = $80\% \times c$
c = maximum quantity (See Table 2)

For JP-8, the equivalent volume is calculated by multiplying the JP-4 volume by a ratio of the JP-4/JP-8 densities.

Fuel Costs

17. JP-4 fuel costs were obtained from historical standing offers over the period 1 February 1995 – 1 February 1996, however, since the mean cost of JP-4 for each wing or base in the period 1 June 1995 – 1 February 1996 was between 1 – 5 ¢/L less then in the period 1 February 1995 – 1 May 1995, it was decided to use the trend established in the latter nine months rather than in the whole period.

18. JP-4 costs were assumed to be normally distributed with mean (μ) and standard deviation (σ) as given in Table 2. Unfortunately, JP-8 costs were not readily available. In the past, PWGSC conducted Price and Availability (P&A) inquiries with the petroleum industry on estimations of cost for JP-8 fuel. The results of these P&A inquiries could not be used for projecting the range of costs between products. The information received from the firms was deemed unreliable as the firms submitted their "uneducated assessment" [4].

Wing/Base	*Max Quantity of JP-4 (c) ($x\ 10^6$ L)*	*Mean Cost (μ) / Standard Dev.(σ) in JP-4 Fuel ($/L)*	*Equivalent Quantity of JP-8 ($x\ 10^6$ L)*
3 Wing Bagotville	45	0.2432/0.0124	42.5
4 Wing Cold Lake	145	0.2186/0.0089	137
8 Wing Trenton	50	0.2499/0.0146	47.2
12 Wing Shearwater	15	0.2437/0.0131	14.2
14 Wing Greenwood	46	0.2487/0.0131	43.5
15 Wing Moose Jaw	30	0.2310/0.0122	28.3
17 Wing Winnipeg	16	0.2331/0.0122	15.1
18 Wing Edmonton	10	0.1980/0.0097	9.4
19 Wing Comox	30	0.2810/0.0074	28.3
CFB Gagetown	2	0.2636/0.0131	1.9
CFB Petawawa	1	0.2448/0.0144	0.9
CFB Valcartier	0.75	0.2250/0.0131	0.7

Table 2. JP-4 and JP-8 fuel requirements for Air Command wings and bases

19. Only 19 Wing Comox uses JP-8 (in actuality Grade Jet A-1 with FSII)[1]. For purposes of costing JP-8 for all other wings and bases, an analysis was conducted where it was assumed that the ratio of the mean JP-8 cost for 19 Wing (for the period 1 June 1995 – 1 February 1996) to the mean JP-4 cost for 19 Wing (for the period 1 February 1995 – 1 May 1995) was the same for each wing and base. For example, for 3 Wing Bagotville, the formula to derive the mean JP-8 cost is:

[1] 19 Wing used JP-4 until 31 May 1995 at which point it switched to JP-8.

$$JP\text{-}8\,(3\,Wing) = \frac{JP\text{-}4\,(3\,Wing)}{JP\text{-}4\,(19\,Wing)} \times JP\text{-}8\,(19\,Wing)\ , \qquad (2)$$

where the mean JP-4 costs for 3 and 19 Wing are given in Table 2. For 19 Wing, the mean cost of JP-8 is 0.2892 ± 0.0081 (\$/L), where the standard deviation of $\pm$ 0.0081 \$/L was used throughout the analysis.

Fuel Analysis

20. A risk analysis on JP-8 fuel costing was conducted using *@RISK*, the statistical simulation software "add-in" to Microsoft Excel[2]. Excel cell values, i.e., fuel volumes and costs for each wing and base, were defined as probability distribution functions as stated above. Output from 1000 iterations of a Monte Carlo simulation allowed determination of the statistics for the difference between the total cost for JP-4 and JP-8 and the sum of the differences.

21. Figure 1 illustrates the results of the simulation for the differences between the purchase and delivery costs for JP-4 and JP-8. The calculations show a net gain in mean purchase and delivery costs of JP-8 for each wing and base. This gain is attributed to the small difference between the average values for JP-4 and JP-8 that were used in calculating the cost differential.

22. Figure 2 shows the cumulative probabilities for the sum of the cost differential between JP-8 and JP-4. The mean (expected) value shows a gain of approximately \$1.91M[3]. At the distribution minimum, the probability is 0% that the loss will be less than -\$3.27M. At the distribution maximum, the probability is 100% that the gain will be less than \$6.00M. There is a 14.1% probability that the cost of using JP-8 relative to JP-4 will incur no additional costs. Table 3 shows the cumulative probabilities and their associated values.

[2] *@RISK* uses simulation to combine all the uncertainties identified in the costing analysis. It is the same software that is used to model the Operational Personnel Risk Assessment Model (OPRAM).
[3] The distribution is skewed normal (non-symmetric) hence the mean at \$1.907M is not equal to the median (50% Probability) at approximately \$2M in Figure 2.

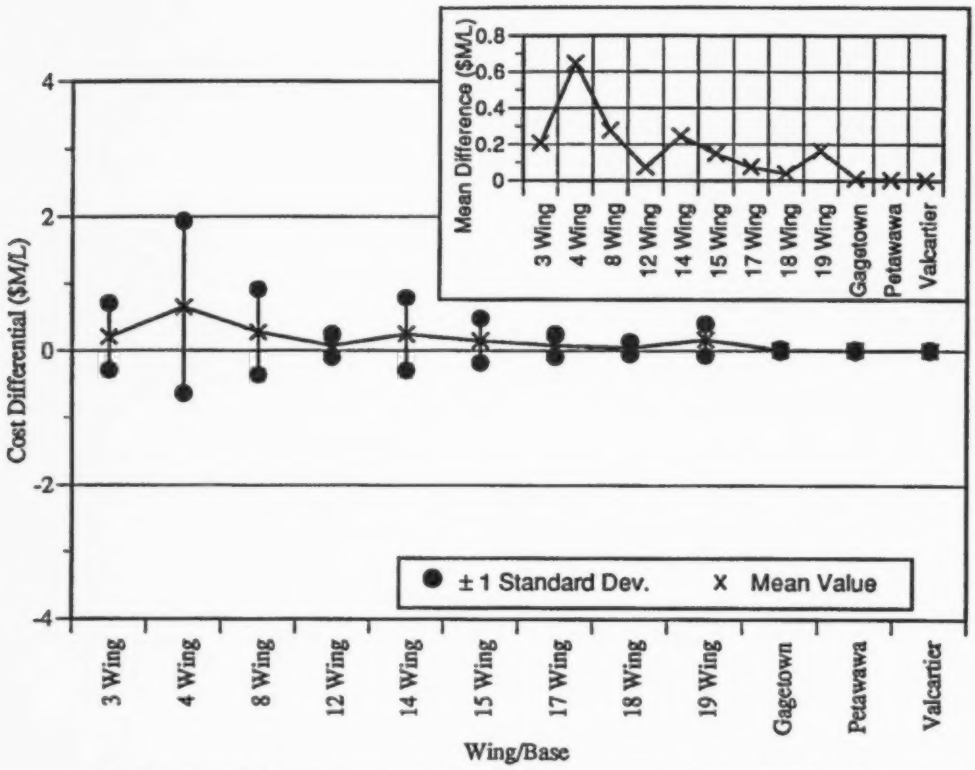

Figure 1. Range of differences in purchase and delivery costs (JP-4 – JP-8) for Air Command Wings and Bases (Insert shows an expansion of the mean difference)

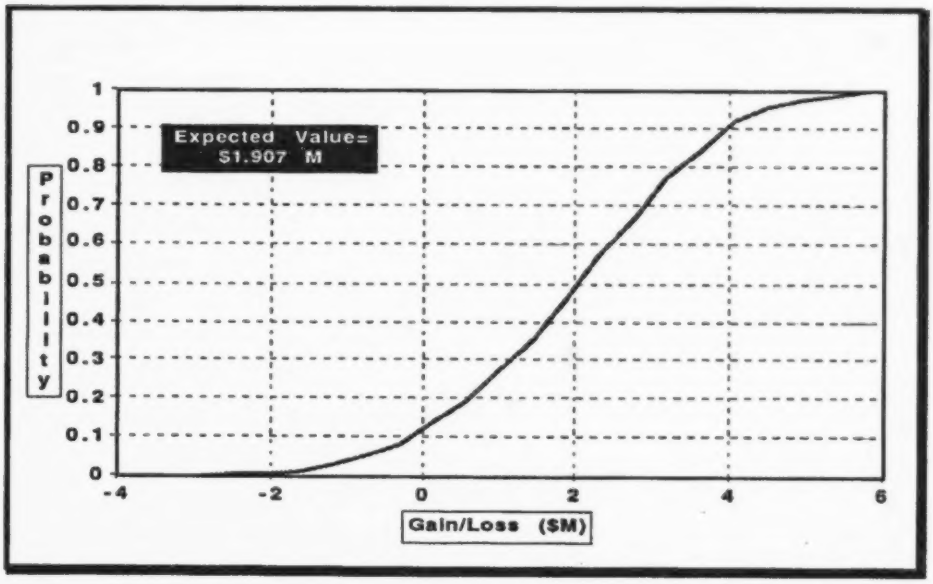

Figure 2. Gain/Loss in the cost and delivery of JP-8 relative to JP-4 (negative values imply a loss)

Probability	Loss/Gain ($M)
0	-$3.27
.10	-$0.33
.20	$0.51
.30	$1.08
.40	$1.60
.50	$1.99
.60	$2.39
.70	$2.87
.80	$3.32
.90	$3.98
1.00	$6.00

Table 3. Probabilities that the Loss/Gain is less than the stated value

4 - DISCUSSION

23. In reference [1], analysis of the cost of conversion to JP-8 for the four largest wings, i.e., 4 Wing, 8 Wing, 14 Wing and 19 Wing, concluded that there was a net loss of $2.75M in the purchase and delivery of JP-8. This loss was attributed to a large difference between the average values for JP-4 and JP-8 that were used in calculating the cost differential. The percentage increase in fuel costs varied from 28% for 4 Wing to 7% for 8 Wing. Bearing in mind the large volumes of fuel that must be purchased, it is easy to explain the loss determined in the analysis.

24. The current analysis, while statistical in nature, is much more encompassing in the details of the cost analysis than reference [1]. All major wings and bases that maintain significant flying operations are analyzed. Historical fuel volumes and costs are used to predict, within statistical accuracy, the total cost differential. As shown in Figure 1, there is now calculated to be a net gain in mean purchase and delivery costs of JP-8 for each wing and base. This gain is attributed to the small difference between the average values for JP-4 and JP-8 and the decrease in volume consumption from JP-4 to JP-8 of approximately 6%. To incur a gain, the percentage difference between the costs for JP-4 and JP-8 must be less than 5.8%, as opposed to the 28% to 7% used for the analysis in reference [1]. The mean percentage difference used in the current analysis is 2.9%.

5 - CONCLUSIONS

25. This study discounts the fuel costs analysis (Section 3) of reference [1]. Due to the smaller differences between the statistical mean values for JP-4 and JP-8 fuel costs, this study now reports a mean gain of $1.91M in the use of JP-8 fuel[4]. Therefore, with an anticipated annual recurring savings of approximately $0.162M[5] [1], the total annual gain in purchase and delivery costs is approximately **$2.07M**. All other factors that impact on the conversion as detailed in reference [1] remain accurate, i.e., operational impact, safety, health and environmental considerations, and supply and availability.

26. Regardless of any cost benefit associated with the purchase and delivery of JP-8 fuel relative to JP-4, DND has no intention of switching from JP-4 to JP-8 for at least the next five years [5,6] largely due to the increased maintenance costs as a result of using JP-8 in older CF aircraft.

27. It is assumed that over time, pricing for JP-4 will continue to escalate due to limited usage. While not attractive at this time, eventual cost increases for JP-4 fuel relative to JP-8 may dictate a switch in the future. This will occur when the savings in purchase and delivery of JP-8 are sufficient to offset the implementation and maintenance costs associated with the use of this fuel.

[4] This gain assumes that the volume of JP-8 purchased is less than the current volume of JP-4 based on the increased density of JP-8 relative to JP-4.

[5] As reported in reference [1], the anticipated annual recurring savings were based on the difference between using JP-8 over JP-4 in fuel vapour purging of bulk storage tanks and losses due to evaporation (working and standing losses).

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[6] Letter to all current aviation fuel suppliers from R. Carrière, Client Service and Commodity Manager; Logistics, Electrical, Fuel and Transportation Directorate, Public Works and Government Services Canada (PWGSC), 6 May 1996.

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DOCUMENT CONTROL DATA

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1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.)
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2. SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable)
UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)
AN ANALYSIS OF THE PURCHASE AND DELIVERY COSTS OF JP-8 AVIATION FUEL

4. AUTHORS (Last name, first name, middle initial)
Desmier, Paul E., Dr.

5. DATE OF PUBLICATION (month and year of publication of document)
JULY 1996

6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)
13

6b. NO. OF REFS (total cited in document)
6

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

8. SPONSORING ACTIVITY (the name of the department project officer or laboratory sponsoring the research and development. Include the address.)
Deputy Chief of Staff Logistics

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)
Project Number 64321

9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written.)

10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)
Research Note 9601

10b. OTHER DOCUMENT NOS. (any other numbers which may be assigned this document either by the originator or by the sponsor)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

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14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

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